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FINAL REPORT

An EM Survey Around the Martha's Vineyard Observatory

N00014-01-1-0957

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We have completed a series of survey lines around the Martha's Vineyard observatory (MVCO) site with a towed seafloor electromagnetic (EM) system. The system measures seafloor porosity to depths of about 20m below the seafloor. Our data show porosity responses from a number of relict channels which are offshore extensions of ponds seen on the Vineyard and which are thought to be glacial sapping valleys. The main node of the MVCO sits within the confines of one such channel, the offshore extension of Edgartown Great pond.

Our data were, as far as logistically feasible, coincident with chirp seismic lines collected the previous summer, and also crossed a number of coring locations and places where a resistivity probe had been deployed. Comparison of our data with these other physical and geophysical data sets will be the subject of further work.

A Towed EM Survey Around the Martha's Vineyard Observatory

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Shallow Water

LONG TERM GOALS

The incorporation of porosity measurements made by electromagnetic (EM) techniques into the suite of physical properties measurements used for mine burial prediction models.

OBJECTIVES

To complete a series of electromagnetic (EM) profiles around the Martha's Vineyard observatory (MVCO) site, providing physical properties information for ONR sponsored mine burial prediction activities. These EM lines were to be, where possible, coincident with seismic reflection lines shot last summer and also coincident with coring, grab-sampling and resistivity probe locations, also completed in cruises last summer.

Previous work suggests that the main node of the observatory sits within the confines of a paleo-channel that marks the offshore extension of the Edgartown Great pond. High resolution chirp data throughout the region have delineated the channel structure. The EM data will augment these results by providing porosity information to depths of about 20m below the seafloor that can be used to understand the nature of the infilling material. In a regional sense, the EM data will identify physical properties of the uppermost seafloor that can be used to understand the facies conditions in the area. Porosity-depth profiles from the EM data can be used as input parameters into mine burial prediction models.

Analysis of seafloor and sub-bottom porosities from EM data will be compared to physical properties throughout the survey region inferred from analysis of seismic reflection amplitudes and to lithology from cores, where applicable.

APPROACH

The data were collected using a new towed EM system built at WHOI and based on one used in previous ONR funded surveys which is operated by the Geological Survey of Canada. The system consists of a transmitter, which generates time varying magnetic

fields over a range of frequencies, and three receivers, tuned to measure these magnetic fields, which are towed at fixed distances of 4m, 13m and 40m behind the transmitter. At a given frequency, the magnetic fields decay in strength away from the transmitter in a manner that depends on the conductivity of the seafloor, and decay more rapidly in more conductive media. This means that if frequencies are chosen appropriately a measured signal will have primary sensitivity to changes in sub-seafloor properties and will not be greatly affected by the overlying conductive seawater. Each receiver is tuned to record three frequencies and the information in each consists of a magnetic field amplitude and phase. Frequencies transmitted range from 200Hz to 200kHz. A set of raw measurements consists of 9 amplitude and phase values at each transmission station along a tow-line. The system is dragged along the bottom at speeds of 2-3 knots and makes a set of reading every 10-20m or so along track.

It is possible to take a set of amplitude and phase values and invert all of them for a resistivity-depth profile. In practice, a more efficient and straightforward means of looking at the data is to take the three amplitudes and phases recorded by each receiver and find the best-fitting apparent resistivity for each: an apparent resistivity is the resistivity of the uniform seafloor halfspace that would best reproduce the observed response. Since all the recorded values have associated errors, and the seafloor is not a half-space, this is only an approximation, but the apparent resistivity does provide a reasonable average resistivity over the depth of sensitivity of each receiver. In general, a receiver that is a distance L away from the transmitter will be sensitive to structure over a depth range up to about 0.5L below the seafloor. By having receivers spaced 4m, 13m and 40m behind the transmitter, we are able to obtain information over the top 20m of seafloor. The apparent resistivity of the 4m receiver provides average structural information about the uppermost 2m of seafloor, the 13m average over about 6-7m while the 40m receiver averages over 20m of seafloor.

Apparent resistivity values are converted into apparent porosities using Archie's law, an empirical relationship relating porosity to electrical resistivity. While this conversion contains several assumptions, the approach has been shown to be reliable for data collected off California through comparisons of EM inferred porosities and core profiles as well as for laboratory measurements on samples.

WORK COMPLETED

The EM system was towed in a series of lines around the MVCO site. Where possible, these lines were coincident with chirp seismic acquisition from the previous summer. However, because the EM system is towed along the seafloor, there were numerous lines close to the MVCO site itself that we were unable to complete for fear of damaging the node or other seafloor instruments. We also extended coverage to the west and east of the seismic box around the MVCO site, providing profiles of porosity along the entire south shore of the Vineyard.

RESULTS

In the records, a number of features are evident:

- There are areas of raised porosities on the 4m and 13m receivers corresponding to the offshore extension of many of the ponds seen on the Vineyard. Similar channel responses were seen in seismic reflection profiling, and we will work to correlate these channel responses as well as to understand the nature of the infilling material. The geometry of the main channel beneath the seismic survey area has been mapped out. The channels in the area are generally quite shallow (extending only a few meters into the sub-bottom) and the porosity contrast between the infill and the surrounding outwash plain sediment is not large (in the range of 5-10%).

- At the extreme western end of our coverage is a region of extremely low porosity (high resistivity) corresponding to the offshore extension of the Miocene unit that forms the bluffs at Gay Head.

- At the southern end of the main survey region are seen rapid variations in the 4m and 13m receiver porosities.

- To the west of the main survey region, apparent porosities on the 40m receiver are higher than on the other two receivers. Although not a large effect, this is unusual and will require verification. One possibility is that due to an error in calibration all porosities on the 40m receiver are a little high (by 3-4%). In any case, the deeper porosities in this area are higher than elsewhere on the south shore.

- The largest signal in the shallowest porosities is seen to the south of Katama Bay, where a broad region of raised porosities is seen.

- Aside from the region of extremely low porosities at the far west of the survey area, two regions of reduced porosity on the 40m receiver are seen, one to the south east of the node, at the eastern edge of the main survey area, and the other to the south west of the node, along the western edge of the survey area.

IMPACT

Our data will have maximum impact once they have been fully merged with the seismic data and intercompared with physical properties measurements made through coring and also by a shallow resistivity probe developed by Larry Mayer at UNH.

Comparison with seismic data will allow us to use the channel geometry defined seismically to guide inversions for true porosity-depth profiles helping us provide details on channel infill material.

The inversion of EM data close to core locations and resistivity probe sites and a comparison of lithology and shallow resistivity data with our own results are expected to be useful for mine burial prediction models.